C

The Target Nutrient Density of a Single Food

As discussed in Chapter 4, planning for groups that include individuals with different nutrient requirements as well as different energy requirements is complicated. This is because individuals vary not only with respect to the amount of food they consume, but also in their choice of foods. However, if all individuals in the group consume a diet consisting of a single, nutritionally complete food (e.g., in an emergency feeding situation), then planners need to account only for the variability across individuals in the amount of food they consume. In this simplified scenario, the target nutrient density in a food can be directly obtained from the distribution of requirements expressed as a density, as described below.

The first step in determining intake of a diet composed of a single food (or of a mix of foods with similar nutrient density) is to obtain a target nutrient density of the food for each subgroup in the heterogeneous group.

Given a distribution of usual energy intakes in the subgroup, what is the target density of the nutrient in the food so that the prevalence of nutrient inadequacy in the subgroup is low? Calculation of the target nutrient density in a single (nutritionally complete) food to achieve a certain acceptable prevalence of inadequate intakes is simple if the distribution of density requirements is available. The concept of a distribution of requirements of a nutrient expressed as a density is now introduced, because it makes the planning of intakes of a diet consisting of a single food a relatively simple task even for a heterogeneous group.

THE DISTRIBUTION OF REQUIREMENTS FOR A NUTRIENT EXPRESSED AS A DENSITY

To obtain the distribution of requirements expressed as a nutrient density, it is necessary to know the distributions of nutrient requirements and the distributions of usual energy intakes in the various subgroups that comprise the target group. For most nutrients for which an Estimated Average Requirement (EAR) has been established, the distributions of requirements have been implicitly assumed to be normal, with mean (and median) equal to the EAR, and the coefficient of variation (CV) of 10 percent (except for niacin, copper, and molybdenum, which have a CV of 15 percent, and vitamin A and iodine, which have a CV of 20 percent [IOM 1997, 1998a, 2000b, 2001]). Even if a nutrient has a skewed requirement distribution, as in the case of iron and protein, the method introduced in this section can still be applied. Following the discussion presented in Chapter 4, it is assumed that estimates of the distributions of usual energy intakes are available for each of the subgroups that comprise the heterogeneous group of interest.

The approach described below to derive the distribution of requirements of a nutrient expressed as a density is flexible. It can be used for any nutrient (including iron, for which the requirement distribution is known to be nonnormal). Because reliable information to derive the distribution of nutrient density requirements when nutrient requirements and energy intakes are not independent is not available, this approach assumes independence.

To derive the requirement distribution of a nutrient expressed as a density, proceed as follows:

1. Simulate a large number *n* of requirements from the distribution of nutrient requirements in the group. For most nutrients, this implies drawing *n* random values from a normal distribution with a mean equal to the EAR of the nutrient in the subgroup and a CV equal to 10 percent of the EAR (15 or 20 percent for some nutrients).
2. Simulate a large number *n* of usual energy intakes from the distribution of usual energy intakes in the subgroup, or in a group that is believed to be reasonably similar in energy intakes to the subgroup of interest.
3. For each pair of simulated nutrient requirements and usual energy intakes, construct the ratio *nutrient requirement/usual energy intake*. The distribution of these *n* ratios is an estimate of the requirement distribution of the nutrient expressed as a density.

As an example, the distribution of vitamin C requirements for nonsmoking women aged 19 to 50 years is assumed to be normal with an EAR of 60 mg/day (IOM, 2000b) and a standard deviation of 10 percent of the EAR, or 6 mg/day. For boys aged 14 to 18 years, the distribution of vitamin C requirements is normal with an EAR of 63 mg/day and standard deviation of 6.3 mg/day. For energy, this example uses normal distributions with means equal to 1,900 kcal/day and 2,300 kcal/day for women and boys, respectively, and a CV of 20 percent to represent the distributions of usual energy intakes in each of the two subgroups. (In practice, the actual usual energy intake distributions would be used to construct the distribution of nutrient requirements expressed as densities. However, the mean energy intakes and CV of energy intake used in this example closely correspond to those that would be obtained from an analysis of the 1994–1996 Continuing Survey of Food Intakes by Individuals [ARS, 1998].)

The Statistical Analysis System program used to derive the distribution of vitamin C requirements expressed as a density in each of the two subgroups is given at the end of this appendix. A sample size of n = 10,000 values of vitamin C requirements and of usual energy intakes for each of the two groups was simulated and the ratio was constructed as described in step 3 above. The resulting two density requirement distributions are shown in Figure C-1.

Notice that the two density requirement distributions shown in the figure are skewed, even though the distributions of vitamin C requirements and of usual energy intakes were assumed to be normal. Notice too that it is possible to compute the mean, median, or any percentile of the derived requirement distributions for the nutrient densities because through the simulation, there are many observations (in this example, 10,000) from each of the distributions.

THE PERCENTILE METHOD TO DERIVE THE TARGET NUTRIENT DENSITY OF A SINGLE FOOD

The target nutrient density of a single food can be directly established from the distribution of nutrient requirements expressed as density that was derived in the preceding section.

In the following illustrations, 3 percent is used as the desired prevalence of inadequate intake. Continuing with the example used earlier, consider the problem of estimating the target vitamin C density in a single food so that the prevalence of inadequate vitamin C intakes in nonsmoking women aged 19 to 50 years and boys

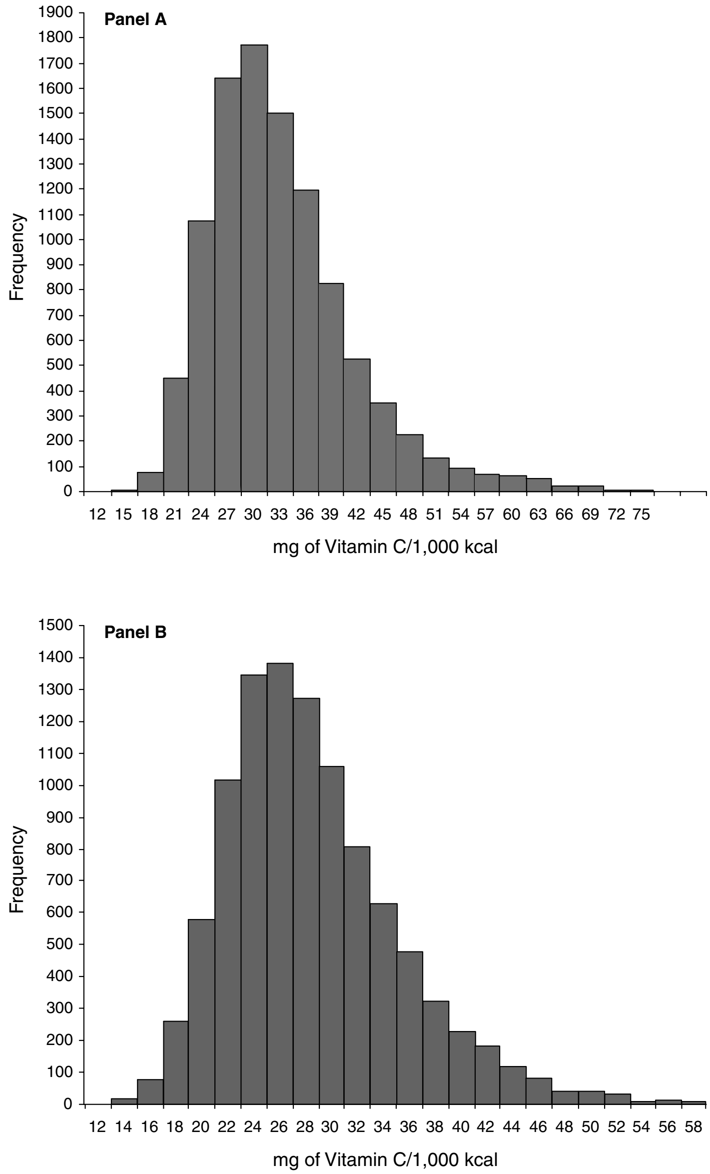

FIGURE C-1 Simulated requirement distributions of vitamin C expressed as densities for nonsmoking women aged 19 to 50 years (Panel A) and for boys aged 14 to 18 years (Panel B). The distributions were constructed using the SAS program presented at the end of this appendix and using information on requirements of vitamin C for the two subgroups (IOM, 2000b). The usual energy intake distributions used in the example are hypothetical.

aged 14 to 18 years does not exceed 3 percent. To obtain the appropriate density, it is necessary to estimate the 97th percentiles of each of the density distributions so only 3 percent would have requirements above this density. In this example, the values obtained are 63.6 mg/1,000 kcal and 42.9 mg/1,000 kcal for women and boys, respectively (see Figure C-1). That is, to ensure that the prevalence of inadequate vitamin C intakes among nonsmoking women aged 19 to 50 years does not exceed 3 percent, the planner must provide a food with a vitamin C density equal to 63.6 mg/1,000 kcal. In the case of boys aged 14 to 18 years, the target vitamin C density in the food is 42.9 mg/1,000 kcal.

To plan intakes of a single food in a heterogeneous group consisting of these two subgroups, the planner would provide a food with vitamin C of density at least 63.6 mg/1,000 kcal, the higher of the two target densities computed above. This is called the reference nutrient density, and is a key tool for planning diets for heterogeneous groups.

The reference nutrient density is defined as the highest target nutrient density among the subgroups in the group being planned for. It is designed to lead to an acceptable prevalence of nutrient inadequacy in the subgroup with the highest target nutrient density. For the entire group, the prevalence of inadequacy would be even lower.

By basing planning on the highest target nutrient density, the planner guarantees that the group with the highest density requirements will have its needs met. In the group with the lowest density requirements, in this case boys 14 to18 years of age, the prevalence of inadequate nutrient intakes will very likely be lower than the target. In fact, the target nutrient density of 63.6 mg of vitamin C/ 1,000 kcal is approximately equal to the 99.5 percentile of the density requirement distribution computed for the boys. Therefore, if the food provided has a vitamin C density of 63.6 mg/1,000 kcal, only about 0.5 percent of the boys in the group will have inadequate vitamin C intakes. This target nutrient density would also need to be evaluated to ensure an acceptably low prevalence of intakes above the Tolerable Upper Intake Level (UL) in the boys. The actual densities derived in this example are for illustration purposes only. In practice, the planner would use a better estimate of the distribution of energy intakes in the subgroups of interest.

The percentile method to obtain the reference nutrient density is very general in that there are essentially no underlying assumptions that must hold for the method to work well. In fact, in principle this approach does not even require that nutrient requirements and usual energy intakes be independent; however, in practice, the independence assumption is made as there is no reliable information that would allow statistical estimation of the joint distribution of nutrient requirement and usual energy intake. Because the derivation of the density requirement distribution and its desirable percentile is done by simulation, it is not even necessary to assume that the distribution of nutrient requirements or of usual energy intakes is normal. Therefore, this approach can be used for iron even though the distribution of requirements is known to be skewed (IOM, 2001).

This percentile approach applies only to planning scenarios where the target group consumes a single food item or mix of foods with very similar nutrient densities. In these scenarios, the variability in intakes across individuals in the heterogeneous group is due only to variability in the amounts of the food (or mix of foods) consumed. In most planning situations, however, individuals vary both in the amount of food consumed and in the choice of the foods they consume. If they choose from a selection of foods with different nutrient densities, then even if the average nutrient density is set as above, it is possible that some individuals will consume the lower-density food items, while others may consume the higher-density food items. When there is heterogeneity in food choices among individuals in a group, one cannot use this simple percentile approach to estimate the necessary food density that will guarantee a low risk of inadequacy for almost all individuals in the group.

MATHEMATICAL PROOF

A simple mathematical proof for the result is presented here. The symbol α is used to denote the nutrient density, or units of the nutrient per 1,000 kcal.

The percentile method attempts to provide an answer to the following question: Given a certain distribution of usual energy intakes, what is the target density, α, of the nutrient so that the prevalence of nutrient inadequacy in the group is low, for example, 2.5 percent?

The result proved below establishes that if the target prevalence of inadequacy is set at $p\%$, then α is the $(1 - p)$th percentile (the upper $[1 - p]$th point) of the distribution of the random variable *nutrient requirement/usual energy intake.*

Proof of Result

To prove that the result presented above is correct, some notation is introduced:

- The symbol x denotes requirement of the nutrient, and is a random variable with some known distribution.
- The symbol y denotes the usual energy intake in the group, and is also a random variable with some distribution.
- The symbol α is the target density or concentration of the nutrient in 1,000 kcal of the food under consideration. Given a usual energy intake equal to y, the target usual intake of the nutrient is equal to αy.

An individual does not have an adequate target intake of the nutrient if $\alpha y < x$, that is, if his or her target usual nutrient intake is less than his or her requirement.

Suppose one wanted to plan a nutrient density so that p% of the group consumes an adequate amount of the nutrient, given a certain distribution of energy intakes in the group.

Find $\alpha \in (0,1)$ such that

$$\Pr(\alpha y > x) = p \tag{1}$$

If x is deleted from both sides of the inequality then equation (1) implies

$$\Pr(\alpha y - x > 0) = p$$

and, therefore

$$\Pr(\alpha - x/y > 0) = p$$

Then

$$\Pr(x/y < \alpha) = 1 - p \tag{2}$$

But expression (2) says that α is larger than x/y with probability $1 - p$ and therefore α has to be the $(1 - p)$th percentile of the distribution of the ratio x/y (by definition of percentile).

Assumptions

The result is true for just about any case. The proof above requires only that x and y be positive. There are no conditions on the distributions of requirements and usual intakes; neither normality nor symmetry of the two distributions is required for the result to hold. In fact, it is not even necessary to assume that intakes and requirements are independent.

However, in order to obtain a numerical value for α, specific distributions for requirements of the nutrient and for energy intakes need to be chosen. Note that the result above holds even if the distribution of requirements happens to be skewed. Thus, the percentile method works for iron in menstruating women.

In the special case in which both the nutrient requirement and the energy intake distributions are normal, it is possible to derive an analytical expression for α.

SAS PROGRAM TO COMPUTE THE REQUIREMENT DISTRIBUTIONS EXPRESSED AS DENSITIES

The program below was used to obtain the two density requirement distributions shown in Figure C-1. Comments are given between /* and */ symbols. The integer numbers given in parentheses after the *rannor* statements are seeds to initialize the random number generators. Any value between 1 and 99999 can be used as a seed. The requirement distribution of a nutrient expressed as a density is needed to plan intakes of a single food or of a diet composed of various foods with similar nutrient density.

```
data one ;
do i = 1 to 10000 ; /* Start simulation of 10,000 vit C requirements
      and energy intakes */
vcreq_w = rannor(675)*6 + 60 ; /* women: vit C req ~ N(60, 6²) */
vcreq_b = rannor(903)*6.3 + 63 ; /*boys: vit C req ~ N(63, 6.3²) */
ereq_w = rannor(432)*380 + 1900 ; /* women: energy intake ~
      N(1900, 380²) */
ereq_b = rannor(500)*460 + 2300 ; /* boys: energy intake ~ N(2300,
      460²) */
ratio_w = (vcreq_w/ ereq_w)*1000 ; /* women: vit C requirements /
      1000 kcal */
ratio_b = (vcreq_b/ ereq_b)*1000 ; /* boys: vit C requirements /
      1000 kcal */
```

```
output ;
end ;
run ;

proc gchart data = one ; /* Obtain the charts in Figure C-1 */
vbar ratio_w ratio_b/ levels = 50 space = 0 ;
run ;

proc sort data = one ; by ratio_w ; /* women: obtain target density
      for single food */
run ;

data temp ; set one ; if _n_ = 9700 ; /* women: 97th percentile of density
      requirements */
run ;

proc print data = temp ; run ; /* women: print target density for
      single food */

proc sort data = one ; by ratio_b ; /* boys: obtain target density for
      single food */
run ;

data temp ; set one ; if _n_ = 9700 ; /* boys: 97th percentile of density
      requirements */
run ;

proc print data = temp ; run ; /* boys: print target density for single
      food */
```